Present Status and Future Directions in Micropropulsion

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Interest in micropropulsion devices is on the rise as new missions with needs for small impulse bits and low thrust levels are beginning to emerge. Also, size, weight and power limitations of future microspacecraft may require extremely miniaturized and highly integrated propulsion hardware. Besides potential microspacecraft missions, such as those envisioned under the New Millennium ST-5 program, or others currently designed, built, and flown by several universities (Cube Sat, University Nanosats) or European institutions (Surrey Space Centre), other missions may also benefit from emerging micropropulsion technologies. These include interferometry or other constellation flying missions, requiring multiple spacecraft to be maintained in a precise formation, requiring small impulse bits and thrust values for positioning control, or large inflatable craft, required to off-set small but continuous solar pressure disturbance torques. Here, micropropulsion devices may be envisioned that could be integrated with the inflatable structures.

Several micropropulsion development efforts are currently under investigation worldwide to address these needs. This paper will review the recent work performed in this field. The number of institutions involved in micropropulsion research and development has increased rapidly in the past few years, involving research in MEMS (Microelectromechanical Systems) based, as well as small conventionally-built micropropulsion hardware. In the MEMS area, resistojets, chemical monopropellant and bipropellant, as well as electric colloid thrusters are being explored. In resistojets, propellant (liquid or gas) is heated in micromachined heater structures and expanded to produce thrust for microspacecraft attitude control. Work in this area is performed by the Aerospace Corp., Air Force Research Laboratories (AFRL) in a team with the University of Southern California (USC), and at the Jet Propulsion Laboratory (JPL). Mono- and bipropellant MEMS thrusters are being studied at NASA Goddard and by MIT, respectively. MEMS colloid thruster work is studied at MIT, JPL, and at the University of Southampton. One area, that involves several independently working groups worldwide, focuses on a concept that is sometimes being referred to as "digital thruster arrays". In this concept, a multitude of single shot thrusters is arranged onto a wafer-level to produce a number of individual impulse bits. Groups working in this field include the Aerospace Corp. in a team with TRW Inc. and Caltech, Honeywell and Princeton University, CNRS in France, and DERA in England.

Work conducted also includes development of physically larger, yet ultra-precise impulse bit thrusters such as FEEP (Field Emission Electric Propulsion) and colloid thrusters, focusing on the interferometry missions, as well as pulsed plasma thrusters (PPT) and micro-ion engines. Work on the latter two concepts does not involve MEMS, yet pushes conventionally machined thruster technologies significantly beyond state-of-the-art limits in small scale. Work on FEEP thrusters is performed at Centrospazio, Italy and ARCS in Austria. Work on a more conventional scale of colloid thrusters is performed at Buseck Corp. and Phrasor Scientific Corp. in cooperation with Stanford University in the US. Micro-ion engine work is performed at JPL and NASA Glenn. Micro-PPTs are being developed by AFRL, and at General Dynamics.

Microvalves are essential for many micropropulsion applications. Microvalve work is being performed by various institutions in the US and abroad, namely Moog, Inc., Vacco Industries Inc. , and Marotta Inc. in the US, and at the Angstroem Institute of the University of Uppsalla in Sweden.

This paper will review current work by these groups. Since many of these projects are still in various stages of development, this survey will also provide a glimpse into the near to intermediate future of micropropulsion technology.